

remarks upon the subject or upon other phenomena noted at the time of the eclipse.

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The observations may be summarised as follows:—

#### OBSERVATIONS OF SHADOW BANDS, AUGUST 30, 1905.

Place .....		
(Situation and altitude) .....		
Observers .....		
	Before totality	After totality
1. Direction of bands, .....	.....	.....
2. Direction of motion, .....	.....	.....
3. Velocity, .....	.....	.....
4. Width of bands, .....	.....	.....
5. Distance apart, .....	.....	.....
Remarks :		
Direction of the wind before totality....., after totality....., and direction from which upper clouds (if any) came.....		

#### THE LATENT IMAGE.<sup>1</sup>

MY inclination has led me, in spite of a lively dread of incurring a charge of presumption, to address you principally on that profound and most subtle question, the nature and mode of formation of the photographic image. I am impelled to do so, not only because the subject is full of fascination and hopefulness, but because the wide topics of photographic methods or photographic applications would be quite unfittingly handled by the president you have chosen.

I would first direct your attention to Sir James Dewar's remarkable result that the photographic plate retains considerable power of forming the latent image at temperatures approaching the absolute zero—a result which, as I submit, compels us to regard the fundamental effects progressing in the film under the stimulus of light undulations as other than those of a purely chemical nature. But few, if any, instances of chemical combination or decomposition are known at so low a temperature. Purely chemical actions cease, indeed, at far higher temperatures, fluorine being among the few bodies which still show chemical activity at the comparatively elevated temperature of  $-180^{\circ}\text{C}$ . In short, this result of Sir James Dewar's suggests that we must seek for the foundations of photographic action in some physical or intra-atomic effect which, as in the case of radio-activity or fluorescence, is not restricted to intervals of temperature over which active molecular *vis viva* prevails. It compels us to regard with doubt the rôle of oxidation or other chemical action as essential, but rather points to the view that such effects must be secondary or subsidiary. We feel, in a word, that we must turn for guidance to some purely photo-physical effect.

Here, in the first place, we naturally recall the views of Mr. Bose. This physicist would refer the formation of the image to a strain of the bromide of silver molecule under the electric force in the light wave, converting it into what might be regarded as an allotropic modification of the normal bromide which subsequently responds specially to the attack of the developer. The function of the sensitiser, according to this view, is to retard the recovery from strain. Bose obtained many suggestive parallels between the strain phenomena he was able to observe in silver and other substances under electromagnetic radiation and the behaviour of the photographic plate when subjected to long-continued exposure to light.

This theory, whatever it may have to recommend it, can hardly be regarded as offering a fundamental explanation. In the first place, we are left in the dark as to what the strain may be. It may mean many and various things. We know nothing as to the inner mechanism of its effects

upon subsequent chemical actions—or at least we cannot correlate it with what is known of the physics of chemical activity. Finally, as will be seen later, it is hardly adequate to account for the varying degrees of stability which may apparently characterise the latent image. Still, there is much in Mr. Bose's work deserving of careful consideration. He has by no means exhausted the line of investigation he has originated.

Another theory has doubtless been in the minds of many. I have said we must seek guidance in some photo-physical phenomenon. There is one such which preeminently connects light and chemical phenomena through the intermediary of the effects of the former upon a component part of the atom. I refer to the phenomena of photo-electricity.

It was ascertained by Hertz and his immediate successors that light has a remarkable power of discharging negative electrification from the surface of bodies—especially from certain substances. For long no explanation of the cause of this appeared. But the electron—the ubiquitous electron—is now known with considerable certainty to be responsible. The effect of the electric force in the light wave is to direct or assist the electrons contained in the substance to escape from the surface of the body. Each electron carries away a very small charge of negative electrification. If, then, a body is originally charged negatively, it will be gradually discharged by this convective process. If it is not charged to start with, the electrons will still be liberated at the surface of the body, and this will acquire a positive charge. If the body is positively charged at first, we cannot discharge it by illumination.

It would be superfluous for me to speak here of the nature of electrons or of the various modes in which their presence may be detected. Suffice it to say, in further connection with the Hertz effect, that when projected among gaseous molecules the electron soon attaches itself to one of these. In other words, it ionises a molecule of the gas or confers its electric charge upon it. The gaseous molecule may even be itself disrupted by impact of the electron if this is moving fast enough and left bereft of an electron.

We must note that such ionisation may be regarded as conferring potential chemical properties upon the molecules of the gas and upon the substance whence the electrons are derived. Similar ionisation under electric forces enters, as we now believe, into all the chemical effects progressing in the galvanic cell, and, indeed, generally in ionised solutants.

An experiment will best illustrate the principles I wish to remind you of. A clean aluminium plate, carefully insulated by a sulphur support, is faced by a sheet of copper-wire-gauze placed a couple of centimetres away from it. The gauze is maintained at a high positive potential by this dry pile. A sensitive gold-leaf electroscope is attached to the aluminium plate, and its image thrown upon the screen. I now turn the light from this arc lamp upon the wire gauze, through which it in part passes and shines upon the aluminium plate. The electroscope at once charges up rapidly. There is a liberation of negative electrons at the surface of the aluminium; these, under the attraction of the positive body, are rapidly removed as ions, and the electroscope charges up positively.

Again, if I simply electrify negatively this aluminium plate so that the leaves of the attached electroscope diverge widely, and now expose it to the rays from the arc lamp, the charge, as you see, is very rapidly dissipated. With positive electrification of the aluminium there is no effect attendant on the illumination.

Thus from the work of Hertz and his successors we know that light, and more generally what we call actinic light, is an effective means of freeing the electron from certain substances. In short, our photographic agent, light, has the power of evoking from certain substances the electron which is so potent a factor in most, if not in all, chemical effects. I have not time here to refer to the work of Elster and Geitel whereby they have shown that this action is to be traced to the electric force in the light wave, but must turn to the probable bearing of this phenomenon on the familiar facts of photography. I assume that the experiment I have shown you is the most fundamental photographic experiment which it is now in our power to make.

<sup>1</sup> Address to the Photographic Convention of the United Kingdom, 1905. By J. Joly, F.R.S.

We must first ask from what substances can light liberate the electron. There are many—metals as well as non-metals and liquids. It is a very general phenomenon, and must operate widely throughout nature. But what chiefly concerns the present consideration is the fact that the haloid salts of silver are vigorously photo-electric, and, it is suggested, possess, according to Schmidt, an activity in the descending order bromide, chloride, iodide. This is, in other words, their order of activity as ionisers (under the proper conditions) when exposed to ultra-violet light. Photographers will recognise that this is also the order of their photographic sensitiveness.

Another class of bodies also concerns our subject:—the special sensitisers used by the photographer to modify the spectral distribution of sensibility of the haloid salts, *e.g.* eosine, fuchsine, cyanine. These again are electron-producers under light stimulus. Now it has been shown by Stoletow, Hallwachs, and Elster and Geitel that there is an intimate connection between photo-electric activity and the absorption of light by the substance, and, indeed, that the particular wave-lengths absorbed by the substance are those which are effective in liberating the electrons. Thus we have strong reason for believing that the vigorous photo-electric activity displayed by the special sensitisers must be dependent upon their colour absorption. You will recognise that this is just the connection between their photographic effects and their behaviour towards light.

There is yet another suggestive parallel. I referred to the observation of Sir James Dewar as to the continued sensitiveness of the photographic film at the lowest attained extremes of temperature, and drew the inference that the fundamental photographic action must be of intra-atomic nature, and not dependent upon the *vis viva* of the molecule or atom. In then seeking the origin of photographic action in photo-electric phenomena we naturally ask, Are these latter phenomena also traceable down to low temperatures? If they are, we are entitled to look upon this fact as a qualifying characteristic or as another link in the chain of evidence connecting photographic with photo-electric activity.

I have quite recently, with the aid of liquid air kindly supplied to me by Mr. Moss, and made in the laboratory of this society, tested the photo-sensibility of aluminium and also of silver bromide down to temperatures approaching that of the liquid air. The mode of observation is essentially that of Schmidt—what he terms his static method. The substance undergoing observation is, however, contained at the bottom of a thin copper tube, 5 cm. in diameter, which is immersed to a depth of about 10 cm. in liquid air. The tube is closed above by a paraffin stopper which carries a thin quartz window as well as the sulphur tubes through which the connections pass. The air within is very carefully dried by phosphorus pentoxide before the experiment. The arc light was used as source of illumination. It was found that a vigorous photo-electric effect continued in the case of the clean aluminium. In the case of the silver bromide a distinct photo-electric effect was still observed. I have not had leisure to make, as yet, any trustworthy estimate of the percentage effect at this temperature in the case of either substance. Nor have I determined the temperature accurately. The latter may be taken as roughly about  $-150^{\circ}\text{C}$ .

Sir James Dewar's actual measurements afforded twenty per cent. of the normal photographic effect at  $-180^{\circ}\text{C}$ . and ten per cent. at the temperature of  $-252^{\circ}\cdot5\text{C}$ .

With this much to go upon, and the important additional fact that the electronic discharge—as from the X-ray tube or from radium—generates the latent image, I think we are fully entitled to suggest as a legitimate lead to experiment the hypothesis that the beginnings of photographic action involve an electronic discharge from the light sensitive molecule; in other words that the latent image is built up of ionised atoms or molecules the result of the photo-electric effect on the illuminated silver haloid, upon which ionised atoms the chemical effects of the developer are subsequently directed. It may be that the liberated electrons ionise molecules not directly affected, or it may be that in their liberation they disrupt complex molecules built up in the ripening of the emulsion. With the amount we have to go upon we cannot venture to particularise. It

will be said that such an action must be in part of the nature of a chemical effect. This must be admitted, and, in so far as the re-arrangement of molecular fabrics is involved, the result will doubtless be controlled by temperature conditions. The facts observed by Sir James Dewar support this. But there is involved a fundamental process—the liberation of the electron by the electric force in the light wave, which is a physical effect, and which, upon the hypothesis of its reality as a factor in forming the latent image, appears to explain completely the outstanding photographic sensitiveness of the film at temperatures far below those at which chemical actions in general cease.

Again, we may assume that the electron-producing power of the special sensitiser or dye for the particular ray it absorbs is responsible, or responsible in part, for the special sensitiveness it confers upon the film. Sir Wm. Abney has shown that these sensitisers are active even if laid on as a varnish on the sensitive surface and removed before development. It must be remembered, however, that at temperatures of about  $-50^{\circ}$  these sensitisers lose much of their influence on the film. [See a paper by me read before the convention in 1894.]

It appears to me that on these views the curious phenomenon of recurrent reversals does not present a problem hopeless of explanation. The process of photo-ionisation constituting the latent image, where the ion is probably not immediately neutralised by chemical combination, presents features akin to the charging of a capacity—say a leyden jar. There may be a rising potential between the groups of ions until ultimately a point is attained when there is a spontaneous neutralisation. I may observe that the phenomena of reversal appear to indicate that the change upon the silver bromide molecule, whatever be its nature, is one of gradually increasing intensity, and finally attains a maximum when a return to the original condition occurs. The maximum is the point of most intense developable image. It is probable that the sensitiser—in this case the gelatin in which the bromide of silver is immersed—plays a part in the conditions of stability which are involved.

Of great interest in all our considerations and theories is the recent work of Prof. Wood on photographic reversal. The result of this work is—as I take it—to show that the stability of the latent image may be very various according to the mode of its formation. Thus it appears that the sort of latent effect which is produced by pressure or friction is the least stable of any. This may be reversed or wiped out by the application of any other known form of photographic stimulus. Thus an exposure to X-rays will obliterate it, or a very brief exposure to light. The latent image arising from X-rays is next in order of increasing stability. Light action will remove this. Third in order is a very brief light-shock or sudden flash. This cannot be reversed by any of the foregoing modes of stimulation, but a long-continued undulatory stimulus, as from lamp-light, will reverse it. Last and most stable of all is the gradually built-up configuration due to long-continued light exposure. This can only be reversed by overdoing it according to the known facts of recurrent reversal. Prof. Wood takes occasion to remark that these phenomena are in bad agreement with the strain theory of Mr. Bose. We have, in fact, but the one resource—the allotropic modification of the haloid—whereby to explain all these orders of stability. It appears to me that the elasticity of the electronic theory is greater. The state of the ionised system may be very various according as it arises from continued rhythmic effects or from unorganised shocks. The ionisation due to X-rays or to friction will probably be quite unorganised, that due to light more or less stable according to the gradual and gentle nature of the forces at work. I think we are entitled to conclude that on the whole there is nothing in Prof. Wood's beautiful experiments opposed to the photo-electric origin of photographic effects, but that they rather fall in with what might be anticipated.

When we look for further support to the views I have laid before you we are confronted with many difficulties. I have not as yet detected any electronic discharge from the film under light stimulus. This may be due to my defective experiments, or to a fact noted by Elster and Geitel concerning the photo-electric properties of gelatin.



They obtained a vigorous effect from Balmains luminous paint, but when this was mixed in gelatin there was no external effect. Schmidt's results as to the continuance of photo-electric activity when bodies in general are dissolved in each other lead us to believe that an actual conservative property of the medium and not an effect of this on the luminous paint is here involved. This conservative effect of the gelatin may be concerned with its efficacy as a sensitiser.

In the views I have laid before you I have endeavoured to show that the recent addition to our knowledge of the electron as an entity taking part in many physical and chemical effects may be availed of, and should be kept in sight, in seeking an explanation of the mode of origin of the latent image.

#### GLACIAL STUDIES IN CANADA.

DR. WILLIAM H. SHERZER has published in the *Smithsonian Miscellaneous Collections* (pp. 453-496) a handsomely illustrated preliminary report entitled "Glacial Studies in the Canadian Rockies and Selkirks." The five glaciers selected are conveniently located in Alberta and British Columbia, and the line of the Canadian Pacific Railway passes near them. Observations have been made on the rate of motion of the Victoria Glacier, which is as low as about 52 feet a year, and on the lowering of its surface by ablation. The front of this glacier shows a shearing movement of one layer over another, as was tested by the pushing forward of iron spikes driven into an upper and a lower stratum. The right lateral moraine receives a certain amount of ground-moraine or sub-glacial material from a hanging glacier on Mount Lefroy, which breaks away in avalanches on to the main Victoria flow. This incident, which is well illustrated, serves to warn us from assuming that all sub-glacial material at a glacier's edge results from plucking action on the wall or floor in contact with the local ice.

A brief but useful discussion of "dirt-bands" follows, in which three types are distinguished. Layers of the glacier may vary in the percentage of foreign matter contained in them, and these stratified dirt-bands may be too thick to represent mere temporary variations in snow-fall, and probably then correspond with short cycles of variation in the "activity of the glacier-making agencies." A second type of dirt-band is that described by Forbes, conspicuous at a distance, and transverse to the length of the ice-stream; the author traces this appearance to the alternation of depressions and ridges, stones and mud becoming washed into the former, and producing the dark bands, which may be bent forward in the central region as the glacier flows. The explanation given is adopted from Tyndall. The greater rapidity of motion in summer produces a crevasse, or a close-set series of crevasses, where there is a marked increase in the drop of the valley-floor. The sun melts out a depression along the line of the crevasse or crevasses, which remains although the fracture heals. In winter, owing to the slower motion, the ice adapts itself better to its inclines, and the few crevasses that are formed are not emphasised at the top by melting. Hence each dirt-band represents a summer season, and the interval a winter one. The third type of dirt-band depends on the greater resistance to melting

offered by blue solid ice, as compared with the intervening layers of vesicular ice. The latter, therefore, form depressions on the melting of the mass, in which detritus gathers, as in the case of the far coarser dirt-bands of the second type. Dr. Sherzer proposes to call a band of the first type a "dirt-zone," and of the third type a "dirt-stripe." The well known blue bands are shown later to have no relation to stratification, and we are left in ignorance as to their origin.

On the lower Lefroy Glacier "ice-dykes" are noted, true mineral veins, as it were, with ice-crystals deposited on their walls and meeting from opposite sides along the central plane. These represent crevasses, which have been healed by the freezing of the water that at one time filled them.

The author's examination of the surfaces of junction of glacier-grains shows that melting opens up a network of delicate tube-like capillaries, which are here photographed—we presume on a natural scale—both before and after injection with potassium permanganate. As melting proceeds, this network disappears, apparently by a general



FIG. 1.—Formation of Forbes's "dirt-bands," Deville Glacier, Selkirks. From Summit Mt. Fox, looking Eastward. Photographed by Arthur O. Wheeler, 1902. Canadian Topographic Survey.

coarsening of the hollows developed between adjacent grains.

We shall hope to hear more of the author's views on "block-moraines," since we cannot help thinking that such phenomena are far too common for the invocation of earthquake-action as a cause. The double moraine below Lough Coumshingaun, in the county of Waterford, would seem to come into this category; and in that case the jointed nature of the rocks higher up the mountain accounts for the preponderance of huge and angular blocks. The discovery of ice-cores within the steep lateral embankments of the Asulkan Glacier raises the question of such embankments in general; and here again we hope for further details. The illustrations, one of which is here reproduced, are richly varied, and are of equal value to the geographer and the geologist.

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